APPLIED ECOLOGY.

Ecology as a special branch of botanical study has been segregated from the broader field only in recent times, the name having been first suggested by Häckel some twenty-five years ago. But like many phases of human knowledge, practically the study of ecology, that is, of the adaptation of plants to their surroundings, has occupied man these hundreds of years. Long before the study of ecology assumed the dignity of a science did practitioners not only study but apply their knowledge for practical purposes in the production of plants. Agriculture and, still more so, silviculture are based upon the recognition of the ecological relations of plants.

The agriculturist goes so far as to create the οἶκος, the environment, and hence needs less knowledge of adaptation. He can create an environment desirable to any plant. But the silviculturist has not the opportunity to the same extent to fit the environment to his crop; he must study the fitting of his crop to the environment, and as his crop is required to persist for a century or so, adapted to both the stable and variable conditions of the environment, the adaptations must be studied with great care, so that the changes in environment may not prove detrimental to his crop. There are many botanists, even those devoted to ecological studies, who have not given thought to all the factors of importance in the environment which need consideration with a plant of such long duration as a tree. That trees are plants, unique in character and differently situated, as regards ecological factors, from the low vegetation, has hardly been realized.

It is in the hope of stimulating development in this direction and to enlist botanists to aid the practitioners that I venture to point out the directions in which more light is desired by the silviculturist.

Besides the general laws of ecology, which establish principles of adaptation, and which have been so satisfactorily elucidated by Schimper, Warming and others, the practitioner is especially interested in definite knowledge regarding particular species in their adaptations to particular conditions; he needs knowledge of the 'silvicultural requirements' of species, which is and has been for a hundred years his term for ecology.

There are stable or practically unchangeable factors, and unstable or variable factors of environment, with which the silviculturist has to deal.

To the stable factors he must find the crop adapted; the variable factors he can to a certain extent control and shape so as to secure satisfactory results.

The stable factors of environment are soil and general or local climate; the unstable are seasonal variations and certain climatic conditions, plant and animal associates, and light.

As regards soil, it is first of all to be considered that chemical constitution plays probably only a small part or practically none; the reliance of tree growth on mineral constituents being relatively small.

For European species a long series of analyses has shown a great variability of ash contents according to the soil on which the tree has grown, proving that a large part of these contents may be simply fortuitous and not essential to the growth. Moreover, the total amount of mineral constituents in a tree is not only very small, but by far the largest portion is found in the leaves and young parts, suggesting again their merely fortuitous presence as a residue of the transpiration current, and mostly not required. For our own species, I am not aware that any extended investigation has been made in this respect.

The physical conditions of the soil, especially with reference to water conduc-

tivity and water storage capacity, are the more important of the edaphic factors.

The most important of the adaptations to be studied here are those of the root systems, gross as well as minute.

We recognize three types, with many gradations between them—the tap-root, the heart-root and the tracing root system. It is evident that the last, shallow-rooted, system is best adapted mechanically to the shallow soils, but since it must supply itself from the surface, its chances of securing sufficient supplies are limited, hence these species are, relatively speaking, not adapted to dry soils or dry atmospheres. On the other hand, the deep-rooting species can secure water from great distances below ground. They would be naturally what the ecologist calls xerophil in their nature. This term is badly chosen, just as the term hydrophil, for the agriculturist, as well as the horticulturist and silviculturist, has amply proved that most plants love neither dry nor wet conditions, although some are more capable of enduring such extreme conditions.

The trees of the swamps, or many of them, are good examples of this adaptability, for they are also often found to occupy the driest soils. They would appear xerophil and hydrophil at the same time, but as a matter of fact they love neither and would thrive much better in such conditions as the farmer or the nurseryman prepares for his crop; it is only in the competition with other, better-adapted forms, that the unfavorable sites are left to them, to which they are still able to adapt themselves.

Some of the deep-rooters have the capacity of modifying their root system and adapting it to shallow soils. Concerning this practically so important phase of ecology we have little or no knowledge as regards our species.

The climatic range of a species in the natural field gives, of course, a first clue to its climatic adaptation, but we know now very well that mechanical barriers to progress, inefficiency in transportation, and mere competition with other forms are sufficient to exclude species from a wider field. The black locust is a most striking example, having from a very confined natural field become almost ubiquitous. Moreover, within the broader climatic range the distribution of the species is not only determined by edaphic adaptation, but by local variations of climate, such as are brought about by variable topography. Our species so far have remained largely unstudied from this point of view. Among the minor variable features of local climate it is specially the frost phenomena which are of importance, and knowledge as to what species are liable to suffer or capable of withstanding these, and under what conditions, during various periods of their life from the young seedling to the mature tree, would be most desirable.

The most important of the variable factors of environment in a forest association is the light, and the adaptability to variable light conditions of the members which make up the community is of the utmost interest to the silviculturist, and should be to the plant ecologist.

But, although the physiological relations of light to plant growth have been studied by botanists, the ecologic relations have been hardly recognized. On this field the ecologists owe an apology to the silviculturists for having failed to perceive the importance, which the latter have pointed out and appreciated for the last hundred years.

Almost the whole art of the silviculturist is based on the recognition of photic adaptations of the different species. Schimper, in his plant geography, fails even to indicate the ecologic character of this factor,

consuming the thirteen pages on which he discusses the factor of light entirely, with explanations of the physiological influence, although in passing he mentions its ecologic value as follows:

"The importance of light from the standpoint of plant geography, although in its influence upon form and life of the plant significant, is much less than that of temperature and hydrometeors; the differences in light intensity from climate to climate are insignificant in comparison with these factors. Yet, until Wiesner accentuated this influence it had usually been undervalued. The difference in intensity of light in the different climatic zones and the increasing duration of sunlight from the equator to the poles leave their impression upon the vegetation. Still more important, to be sure, is the significance of light for plant topography, since for the characterization of the single formations of a region the great differences of lighting are important."

But for any expansion on this part, namely, the topographic importance of light, we look in vain.

The relative tolerance or endurance of light among the tree species within a given climatic range is probably the most important ecologic factor which determines the character of the association. The tolerant, if adapted to climate and soil, must ultimately drive out or reduce in number the intolerant or light-needing, even though perfectly adapted to climate and soil. This accounts for the sporadic occurrence in the mixed maple-beech-hemlock-spruce forest of such light-needing species as the black cherry, the ash, the elm. It accounts for the existence of the most intolerant bald cypress or larch in the swamps, where their competitors could not follow. It accounts for the change of forest type under the influence of man, the alternation of species observed on burns and slashings.

An ecological study of the relative shade endurance of our important species is the most important need of the silviculturist.

And so we might enumerate any number of problems of practical importance for the solution of which the practitioner is waiting. And as in other sciences, which were first deduced from empirics and now direct the practice, so for ecology has come the time to direct the practice.

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*WORK OF THE LICK OBSERVATORY.**

THE Lick Observatory suffered an irreparable loss in the untimely death on August 12, 1900, of Dr. James Edward Keeler, director from June 1, 1898. Our appreciation of his worth has not grown dim with time. Dr. Keeler's last observations were made with the Crossley Reflector in the hope of recording the image of a ninth satellite of Saturn, reported to exist by Professor W. H. Pickering. No trace of the satellite was detected, but the plate of June 28, 1900, led to the discovery of an asteroid, 1900 GA—probably the faintest one known.

While the Observatory is preeminently an observation station, yet it is not so in a narrow sense. Success in observational work demands: (1) Knowledge of what has been done by others; (2) knowledge of pending problems, and of the most promising methods for their solution; (3) knowledge as to how observations will be used, and when they should be made, in order that they may bear most efficiently upon the problem. An institution whose efforts were confined strictly to securing observations would soon be making inferior observations. Progressive observers must be acquainted with the theories of their

* Abstract of the Director's Biennial Report, Lick Observatory, University of California, July 1, 1900, to July 1, 1902.